Original Paper

Caries Research

Caries Res 2014;48:244–253
DOI: 10.1159/000356859

Received: January 24, 2013
Accepted after revision: October 21, 2013
Published online: February 12, 2014

Value for Money: Economic Evaluation of Two Different Caries Prevention Programmes Compared with Standard Care in a Randomized Controlled Trial

J.H. Vermaire[a, b] C. van Loveren[c] W.B.F. Brouwer[d] M. Krol[d]

[a]TNO Life Style – Behavioural and Societal Sciences, Leiden; [b]Department of Social Dentistry and Behavioural Sciences and [c]Department of Experimental Preventive Dentistry, Clinical Cariology and Microbiology, Academic Centre for Dentistry Amsterdam (ACTA), Amsterdam; [d]Institute of Health Policy and Management, Erasmus University, Rotterdam, The Netherlands

Key Words

Caries prevention programmes · Economic evaluation · Randomized controlled trial · Standard care

Abstract

A cost-effectiveness analysis was conducted during a 3-year randomized controlled clinical trial in a general dental practice in the Netherlands in which 230 6-year-old children (± 3 months) were assigned to either regular dental care, an increased professional fluoride application (IPFA) programme or a non-operative caries treatment and prevention (NOCTP) programme. Information on resource use during the 3-year period was documented by the dental nurse at every patient visit, such as treatment time, travel time and travel distance. Caries increment scores (at D_3MFS level) were used to assess effectiveness. Cost calculations were performed using bottom-up micro-costing. Incremental cost-effectiveness ratios (ICERs) were expressed as additional average costs per prevented DMFS. The ICERs compared with regular dental care from a health care system perspective and societal perspective were, respectively, EUR 269 and EUR 1,369 per prevented DMFS in the IPFA programme, and EUR 30 and EUR 100 in the NOCTP programme. The largest investments for the NOCTP group were made in the first year of the study; they decreased in the second and equalled the costs of control group in third year of the study. From both medical and economic points of view, the NOCTP strategy may be considered the preferred strategy for caries prevention.

Health care expenditures related to dental care have increased rapidly in recent years. For instance, in the Netherlands, the costs of dentistry increased by 10% between 2007 and 2010 [Poos et al., 2008; Slobbe et al., 2011]. In many countries, high and increasing health care expenditures have raised questions about the amounts of money that should be spent on health care, as well as the justifications for these amounts. Achieving an optimal allocation of scarce societal and health care resources can be supported by economic evaluations of health care interventions. In economic evaluations, the costs of an intervention are compared to its benefits. Economic evaluations can be used to determine the relative efficiency of a new intervention compared with one or more alternatives.

Caries is one of the most prevalent diseases among schoolchildren in the Netherlands. In 2005, 56% of 5-year-olds experienced one ore more carious lesions in their deciduous teeth, while 71% of the 17-year-olds had one or

KARGER

E-Mail karger@karger.com
www.karger.com/cre

0008–6568/14/0483–0244$39.50/0

J.H. Vermaire
TNO Life Style – Behavioural and Societal Sciences
Wassenaarseweg 56
NL–2333 AL Leiden (The Netherlands)
E-Mail erik.vermaire@tno.nl

more carious lesions in their permanent dentition [Poorterman and Schuller, 2006]. Caries is present, although unequally distributed, throughout all socioeconomic classes in both developing and developed countries [Petersen, 2003; Bagramian et al., 2009]. As a result, a large proportion of the total dentistry budget is spent on treatment of dental caries; in the Netherlands, this share is 60% [Slobbe et al., 2011]. In 2007, the health care costs related to caries were EUR 1.8 billion. This amount is equal to the costs related to coronary heart disease [Poos et al., 2008].

Many caries prevention programmes focus on professionally performed fluoride applications [Marinho et al., 2002]. Some programmes focusing on intensified self-care have been developed during the past decades [Carvalho et al., 1992; Ekstrand et al., 2000; Ekstrand and Christiansen, 2005; Hausen et al., 2007]. Considering the allocation of scarce (health care) resources, it is important to have insight into both the costs and the effects of different prevention strategies and thus their relative cost-effectiveness. Such insight can help communities make best use of budgets for oral health. Note that in order to make well-balanced decisions, it is important to also consider the opportunity costs of, for instance, implementing new health care interventions. Especially in systems operating under a fixed health care budget, implementing a new intervention may need to be financed by limiting the expenditures on other interventions. With open-ended financing systems, implementing and reimbursing new, costly interventions results in higher total health care expenditures, which comes at the expense of other public and private spending.

This study aimed to assess the cost-effectiveness of caries treatment and prevention strategies in the Netherlands. In the Netherlands, a tradition of regular visits to the dentist (preventive check-ups) exists. In 2011, approximately 82% of 5-year-old children had visited the dental practice in the preceding 6 months and 95% in the preceding year. For 11-year-old children, the figures were 89 and 98%, respectively [Schuller et al., 2013].

This cost-effectiveness study was performed alongside a randomized controlled trial evaluating the effects of two caries prevention strategies compared with regular dental care among 6-year-olds. This trial included a regular treatment and prevention approach (control group), an increased professional fluoride application (IPFA) approach and a non-operative caries treatment and prevention (NOCTP) approach based on earlier literature [Carvalho et al., 1992; Marinho et al., 2002; Ekstrand and Christiansen, 2005].

Methods

Interventions and Participants

From September 2006 to September 2008, all parents of regular patients aged 6.0 years (± 3 months) of a large dental clinic in 's Hertogenbosch (a medium-sized city in the Netherlands with approximately 150,000 inhabitants) were asked for consent to include their child in a randomized controlled trial on caries-preventive strategies. A total of 230 children were included in this study and were randomly assigned to one of the following three groups:

(1) Control group. This group received standard dental care: dental check-ups twice a year, including professional fluoride gel applications (1.23% F^-) and preventive pit and fissure sealants after eruption of the permanent molars, on a routine basis. The threshold for placing restorations was set at the d3/D3 level.

(2) IPFA group. Like the control group, the IPFA group received standard dental care but had two additional professional fluoride gel applications. Children in this group therefore received a total of four professional fluoride applications per year.

(3) NOCTP group. The NOCTP protocol was copied from a study that Ekstrand and Christiansen had performed in Nexø, Denmark [2005]. Recall intervals were individualized using criteria described by Carvalho et al. [1992]: caries activity, oral hygiene, eruption stage of permanent molars, and cooperation of child and parent. At each visit, areas where plaque removal and fluoride toothpaste needed to be more effectively applied were identified and instruction was given how to clean these areas. If progression of the caries process was controlled, fluoride varnish was applied locally. If, at a following visit, there was still no stabilisation or caries inhibition, the surface was sealed or, if the caries process had reached the D3 level, it was restored.

Data on time and resource use as well as data on effectiveness were collected for the 3-year time period of the randomized controlled trial. The study was approved by the Medical Ethical Committee of the Free University of Amsterdam, The Netherlands (protocol number NL13709.029.06).

Costs

Costs and therefore cost-effectiveness can be calculated from both a health care system perspective as well as a societal perspective. Adopting a health care system perspective, cost inclusion is limited to only medical costs, i.e. the costs of the treatment and prevention of caries. Adopting a societal perspective, all relevant societal costs are included. Hence, besides medical costs, costs such as out-of-pocket expenses (e.g. toothbrushes, toothpaste), travel costs to the clinic, travel time and time required to accompany the child are then included in the evaluation, regardless of where these costs incur [Drummond et al., 2005]. Countries differ regarding the prescribed or preferred perspective to take in economic evaluations. For example, governments in Sweden, Finland, France and the Netherlands recommend a societal perspective, while in the USA, Germany and the UK a health care system perspective is often applied. To gain comparability to other studies and to collect information on what the influence of the chosen perspective is in this type of study in preventive dentistry, this study was conducted from both a health care and a societal perspective.

Health Care Resource Use and Costs

Calculations were performed according to the recommendations in the Dutch manual for costing [Hakkaart-van Roijen et al.,

2010; Tan et al., 2012]. A bottom-up micro-costing approach was used to calculate medical costs. Instead of using fixed prices for each treatment strategy, cost-prices were determined per individual patient based on the number of minutes the dental professional spent on the patient. At every visit to the dental clinic, the number of minutes that the dentist and/or the dental preventive nurse/dental hygienist spent on each patient was documented.

Cost-prices in this study were based on the actual expenditures of the dental clinic. These cost-prices were based on both gross incomes of the dental professionals and a share of the supplementary costs of the dental clinic (e.g. costs for materials, housing and management). Gross incomes and all other expenditures of the dental clinic were divided by the number of 'productive hours' (hours spent on patient care) of the dental professionals (dentists, oral hygienists and dental nurses). It was assumed that 88.5% of working hours were spent on patient care and 11.5% on non-patient work, such as training, conference meetings and non-patient administrative work. These percentages were based on a survey among Dutch dentists in 2010 [Kalf et al., 2010]. The dental clinic's costs were divided among the various professionals based on their respective gross incomes. In this way, the cost-price per minute was calculated to be EUR 2.60 for the dentist, EUR 0.78 for the dental hygienist and EUR 0.70 for the dental nurse. To calculate the medical costs, the calculated cost-prices per minute were multiplied by the number of minutes that the dental professional spent on the particular patient.

Societal Resource Use and Costs

At every visit to the dental clinic, data on travel time and travel distance were collected. Travel costs were calculated based on a price of EUR 0.20 per kilometre for both private and public transportation [Hakkaart-van Roijen et al., 2010]. Time costs of the adult accompanying the child consisted of travel time, time with the dental professional and an estimated mean waiting time of 7 min. This waiting time was based on the average waiting time reported in the latest survey of the Dutch Consumers Association [Nivel/Dutch Consumers Association, 2002]. Waiting time for the child itself was not taken into account in the cost calculation. Time costs were valued at EUR 12.50 per hour, in line with the Dutch health pharmacoeconomic guidelines [Hakkaart-van Roijen et al., 2010].

To correct for the rise of general levels of prices of goods and services (inflation) during the experiment, prices were converted to 2011 euros.

Effects

The outcomes of the clinical trial were used to establish the effectiveness of the programmes. Effectiveness was expressed as the number of prevented DMFS. DMFS scores were determined based on clinical examinations that were carried out by a dentist who was blinded to the treatment groups. At baseline and after 3 years, 11 and 10% respectively of the children were re-examined by a second blinded dentist. Inter-examiners agreement scores on dmfs/DMFS were $\kappa = 0.89$ and $\kappa = 0.91$, respectively. Both examiners were not involved in the dental care of the children and were not employed in the dental practice. Due to medical-ethical objections, no radiographs were taken for the purpose of this study. As a result, caries was only clinically assessed. Caries was scored at the D3 level (caries into dentin).

Discounting

In economic evaluations, costs and benefits occurring at different points in time are weighted differently. An important rationale for this is time preference: the human tendency to prefer to enjoy benefits as soon as possible and to postpone costs as long as possible. In order to correct for this time preference, values in the future are devalued, commonly by a constant annual percentage. The more distant costs and effects are in time, the more they are discounted and, hence, the less weight they receive in current decisions [Bonneux and Birnie, 2001; Brouwer et al., 2005]. The discount percentages used are not equal worldwide and are a topic of much debate [Claxton et al., 2011]. In this study we followed the Dutch pharmacoeconomic guidelines applying 4% for costs and 1.5% for effects in the second and third year, while costs and benefits in the first year were not discounted [College voor Zorgverzekeringen, 2006]. Discounting may seem a rather technical procedure, but it can have considerable impact on the cost-effectiveness outcomes, certainly in preventive health care which typically involves current costs and future benefits. To identify the possible effect of discounting in this specific situation, both discounted and undiscounted data are presented.

Cost-Effectiveness

Incremental cost-effectiveness was expressed as the additional average costs per prevented DMFS. The incremental cost-effectiveness ratio (ICER) was calculated by dividing the differences in costs between the experimental group and the control group by the differences in effects. Two ICERs were calculated: IPFA compared with regular care and NOCTP compared with regular care.

$$\text{ICER} = \frac{\left(\text{Experimental group costs} - \text{Control group costs}\right)}{\left(\text{Experimental group DMFS} - \text{Control group DMFS}\right)}.$$

Sensitivity and Scenario Analyses

Univariate sensitivity analysis was conducted to assess the impact of labour costs on the study results. In the base case analyses, the salaries for a dentist, a dental hygienist and a dental assistant were EUR 75,000, 30,000 and 25,000 per full-time equivalent (FTE), respectively. Varying the dentists' salaries from EUR 45,000 to EUR 100,000, the dental hygienists' salaries from EUR 25,000 to EUR 45,000 and the dental assistants' salaries from EUR 20,000 to EUR 35,000 resulted in cost-prices per minute of EUR 1.70 and 3.03 for a dentist, EUR 0.67 and 1.08 for a dental hygienist and EUR 0.66 and 0.95 for a dental assistant.

Task delegation and task reallocation have become increasingly relevant in both medicine and dentistry [Horrocks et al., 2002; Jerkovic et al., 2010]. With these changes the field of work for dentists would focus on restorative treatment, endodontic treatment and provision of fixed and removable prosthetic care, while the field of work of dental hygienists would broaden and their workload would increase. Such a scenario seems applicable for the two interventions studied. Hence, we investigated the impact on cost-effectiveness of a scenario in which all preventive visits would be performed by a dental hygienist instead of the dentist, to gain comparability with other studies. In doing so, for the cost-price calculations, an assumption was made that the workload for dental hygienists in the clinic would have increased from 4.0 to 5.3 FTE and dentists' workload would have decreased from 5.3 to 4.0 FTE.

Therefore, the dental clinic's costs and the allocation of these costs to the dental professionals would change, resulting in a cost-price per minute increase from EUR 0.78 to EUR 0.81 for a dental hygienist and a cost-price per minute increase from EUR 2.60 to EUR 2.69 for a dentist.

Statistical Analysis and Missing Data

All randomized patients (whose DMFS scores had been determined at baseline by the dentists) were included in the economic evaluation. Multiple imputation was used to account for missing data regarding health care use, travel time and DMFS after 3 years. Each missing value was replaced with predicted values based on health care use, travel time and DMFS outcomes of patients from the same treatment group with similar characteristics (DMFS at baseline and socioeconomic status). This process was performed five times to account for the uncertainty caused by estimating missing data. Each imputed data set was analysed separately and the results were averaged. Non-parametric bootstrapping [Campbell and Torgerson, 1999] was used to address the uncertainty associated with the fact that the data that were collected for the measures of incremental costs and effects were based on a sample of the population. To construct confidence intervals around the differences in mean costs and effects between the caries prevention strategies, 10,000 random samples were drawn from the data. The difference in costs and effects of these 10,000 samples were displayed in cost-effectiveness planes in scatterplots where each point in the cloud represents the outcomes of one of the randomly drawn samples. Moreover, the bootstrap results were presented in cost-effectiveness acceptability curves. The curves indicate the probability (placed on the y-axis) of the IPFA or the NOCTP strategy being cost-effective at different willingness to pay values (placed on the x-axis) for one prevented DMFS.

Data were analysed with Stata SE 12.1 and SPSS 21.

Results

Patients

A total of 230 children started this trial at the age of 6 years. As shown in figure 1, at the age of 9 years, 179 children had completed the 3-year trial: 63 in the regular dental care programme, 62 in the IPFA programme and 54 in the NOCTP programme. Dropout rates were highest in the NOCTP group (32%) versus 20% in the IPFA group and 15% in the control group. In the NOCTP group, the main reason for ending participation was the burden of travel; in the IPFA group and the control group, the main reason was the inconvenience for the child (gagging because of the fluoride gel-filled trays). The baseline DMFS scores of children dropping out of the study (0.11 ± 0.50) did not significantly differ from the baseline DMFS scores of children who did not drop out (0.05 ± 0.25) (F = 2.15; p = 0.15). For deciduous dentition this difference was not significant either: 6.81 ± 9.16 vs. 5.54 ± 8.01 (F = 0.97; p = 0.33).

Table 1. Resource use

	Year 1	Year 2	Year 3	Total
Mean contact time dentist, min				
NOCTP	14	11	9	34
IPFA	14	13	12	39
Control	11	10	10	30
Mean additional contact time dental auxiliaries, min				
NOCTP	1	1	0	3
IPFA	14	13	13	39
Control	6	7	7	20
Mean number of visits to dental clinic				
NOCTP	3.2	2.5	2.0	7.7
IPFA	3.9	3.7	3.5	11.2
Control	2.5	2.4	2.3	7.1
Mean total accompanying time, min[1]				
NOCTP	38	30	23	91
IPFA	55	52	50	156
Control	34	33	32	99

[1] Including travel time, contact time in clinic and waiting time (estimated at 7 min/visit).

Resource Use

Table 1 shows the direct medical and non-medical cost-related variables. Mean total dental professional's contact time and this contact time stratified according to profession (dentist or dental hygienist/dental preventive nurse) is presented. In the first year, the dentist's contact time for children in the NOCTP group was almost 25% higher than that of children in the control group. The mean number of minutes of contact at the dental auxiliaries, however, was almost 17% of that in the control group. In the third year, contact time with dentists as well as with dental auxiliaries was less than in the control group. Similarly, in the first year travel time was higher in the NOCTP group than in the control group, but in the third year travel time was equal in both groups. Contact time and accompanying time in the IPFA group was approximately 56 and 66% higher than in the control group, respectively. Also, the mean numbers of visits and distance travelled (in kilometres) were higher in the IPFA group (79 and 61%) than in the regular care group.

In table 2, both discounted and undiscounted cost outcomes are presented from a health care system perspective and a societal perspective for the total period of 3 years. Mean discounted total health care costs were EUR 90 for the NOCTP group, EUR 120 for the IPFA group and EUR 85 for the control group. The total discounted societal costs (parental investments in terms of accompa-

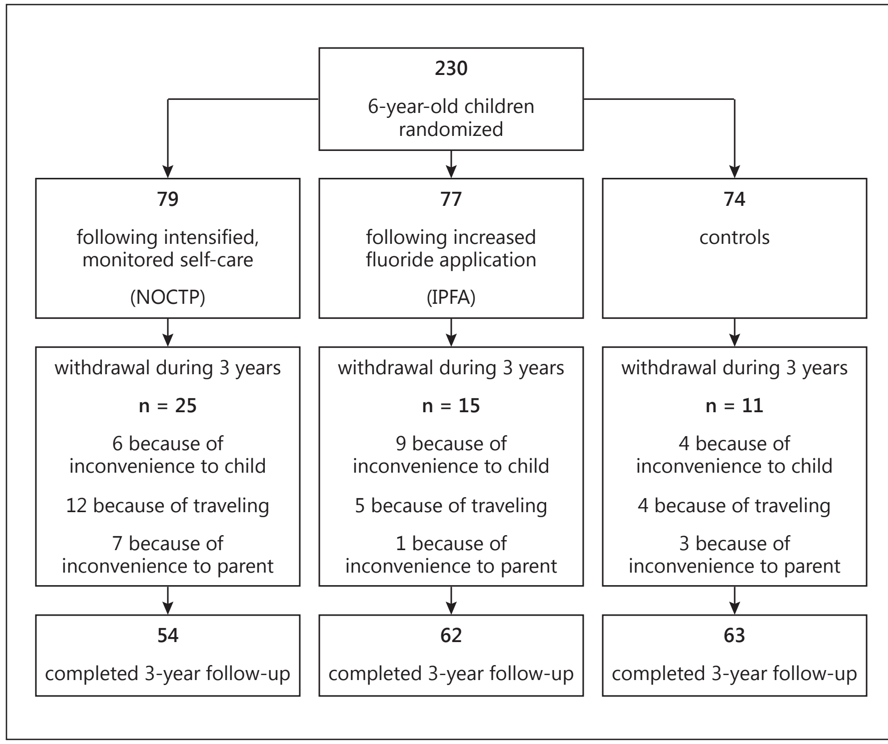

Fig. 1. Flowchart of participation in the study.

Table 2. Mean costs per regimen (2011 euros)

	Year 1	Year 2	Year 3	Total[1]	
				discount rate 0%	discount rate 4%
Health care costs					
NOCTP	38	30	23	94 (88–100)	90 (85–97)
IPFA	45	42	41	125 (117–133)	120 (113–128)
Control	32	31	30	88 (83–95)	85 (79–91)
Time and travel costs					
NOCTP	98	77	60	235 (217–253)	227 (210–245)
IPFA	131	124	120	369 (347–390)	356 (334–375)
Control	82	79	76	222 (204–239)	213 (196–230)
Total costs					
NOCTP	137	107	84	329 (308–351)	318 (297–340)
IPFA	176	166	160	494 (468–519)	476 (451–500)
Control	114	110	106	310 (330–290)	298 (279–317)

Figures in parentheses are 95% confidence intervals. [1] Bootstrapped imputed means.

nying time, travel time and travel costs) were EUR 227, 356 and 213, respectively.

Effectiveness

The discounted and undiscounted caries increment scores of the three groups are presented in table 3. Compared to the control group, the IPFA group had on average 0.14 lower DMFS increment scores and the NOCTP group had on average 0.20 lower DMFS increment scores 3 years after the start of the trial.

Incremental Cost-Effectiveness

From a health care system perspective, the ICER (average costs of preventing one DMFS) of the IPFA group compared with regular care was EUR 269 per additional prevented DMFS, and from the societal perspective, the ICER was EUR 1,369 (table 4). The ICERs of the NOCTP group compared with regular care were EUR 30 from the health care system perspective and EUR 100 from the societal perspective.

Sensitivity and Scenario Analysis

Table 5 shows that varying the salary of the dentist would result in large differences in ICER values (societal perspective) between EUR 62 and 81 per extra prevented DMFS in the NOCTP group and between EUR 1,255 and 1,382 per extra prevented DMFS in the IPFA group. From a societal perspective, in the scenario that the dental hygienist would have performed the intervention, the NOCTP strategy dominated regular care (i.e. it resulted in lower costs and lower DMFS scores). The ICER was EUR 726 for IPFA compared with regular care.

Uncertainty

The results of bootstrapping (10,000 bootstraps) are presented in figure 2 for both experimental groups and for both the health care and the societal perspective. For the NOCTP group, approximately 85% of the bootstrapped replications are located in the east quadrants of the cost-effectiveness graph, indicating an increase in prevented DMFS compared to the regular care group; for the IPFA group, approximately 70% are located in these quadrants. About half of the bootstrap replicates for the NOCTP group are above and about half are below the horizontal axis; this indicates that the costs for the NOCTP group could either be lower or higher than the costs for regular dental care. For the IPFA strategy, all bootstraps indicate an increase in costs compared to regular care.

The cost-effectiveness acceptability curves are presented in figure 3. These curves indicate the probability of the IPFA approach or the NOCTP strategy being cost-effective at different willingness to pay values for a prevented DMFS. As figure 3 shows, considering a societal willingness to pay of EUR 100 on average in 3 years for an additional prevented DMFS, the probability of the NOCTP strategy being considered cost-effective from a health care system perspective is approximately 85% and the probability of the IPFA strategy being cost-effective is approximately 9% and respectively 51 and 0% from a societal perspective.

Table 3. Discounted and undiscounted effects

Caries scores at baseline (DMFS 6 years)	
Control	0.02
NOCTP	0.06
IPFA	0.05
Caries scores after 3 years (DMFS 9 years)	
Control	0.57
NOCTP	0.41
IPFA	0.47
Caries increment (ΔDMFS), discount rate 0%	
Control	0.55
NOCTP	0.35
IPFA	0.42
Caries increment (ΔDMFS), discount rate 1.5%	
Control	0.54
NOCTP	0.34
IPFA	0.40

Table 4. ICERs

	Health care system perspective, discounting		Societal perspective, discounting	
	0%	4% costs 1.5% effects	0%	4% costs 1.5% effects
NOCTP vs. control				
Δ costs	5	6	19	20
Δ effects	0.21	0.20	0.21	0.20
ICER	24	30	90	100
IPFA vs. control				
Δ costs	37	35	184	178
Δ effects	0.14	0.13	0.14	0.13
ICER	265	269	1,314	1,369

Table 5. ICERs sensitivity and scenario analyses

Intervention	Salary dentist EUR 45,000	Salary dentist EUR 100,000	Intervention performed by dental hygienist, salary EUR 30,000
Health care system perspective			
NOCTP vs. control	dominant	EUR 18	dominant
Societal perspective			
NOCTP	EUR 62	EUR 81	dominant
Health care system perspective			
IPFA vs. control	EUR 198	EUR 325	dominant
Societal perspective			
IPFA	EUR 1,255	EUR 1,382	EUR 726

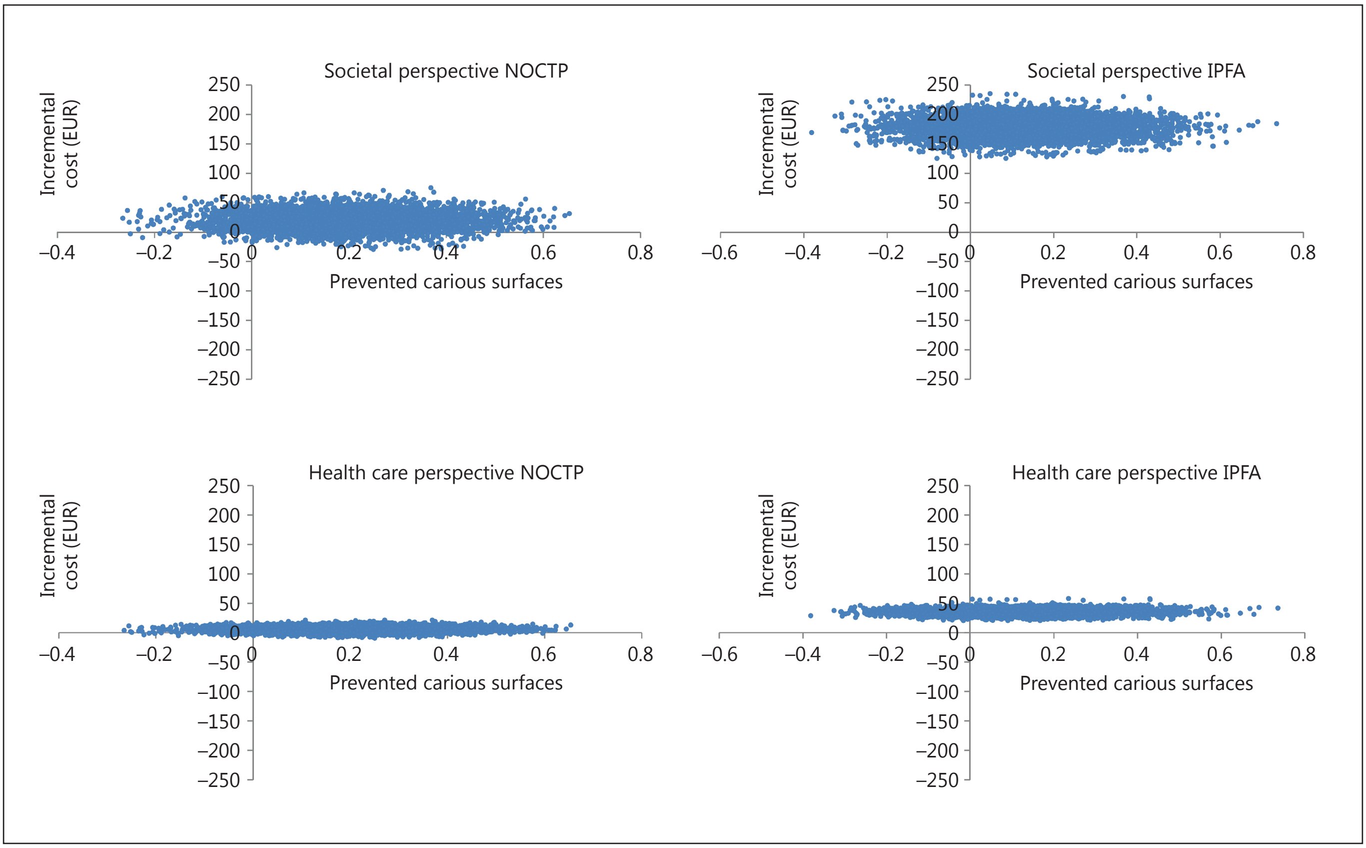

Fig. 2. Cost Effectiveness Plane 10,000 bootstrap replicates of costs and effects for NOCTP and IPFA compared to the control group in both health care system perspective and societal perspective.

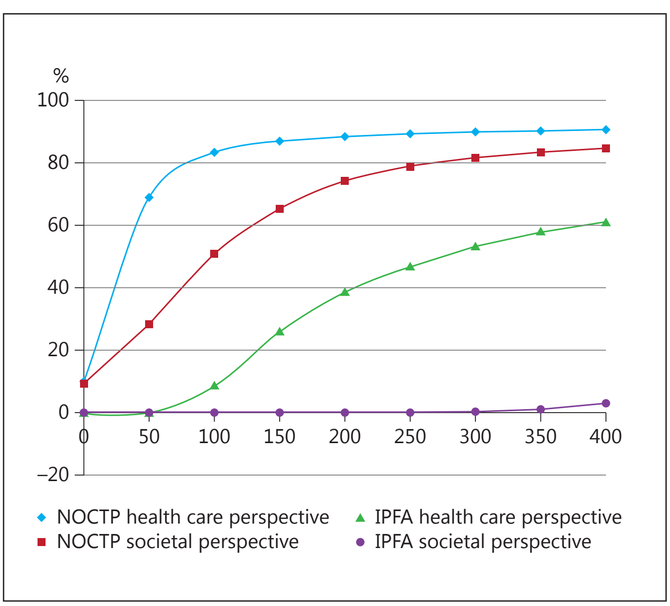

Fig. 3. Acceptability curve: probability of number of bootstraps being cost-effective at different willingness to pay values (in EUR).

Discussion

In this study, the NOCTP strategy, based on intensified and individualized parental homecare, was more effective but more costly than regular caries prevention comprising two dental preventive visits a year, professional fluoride application and sealing of newly erupted permanent molars. The additional health care cost to prevent one DMFS was EUR 30. If the societal perspective was adopted, the additional cost was EUR 100. An alternative approach comprising the control strategy with additional professional fluoride applications (IPFA) was also somewhat more effective than regular care. The costs of this approach were, however, higher than the costs of the NOCTP strategy. The ICERs for IPFA compared with regular care were EUR 269 (health care system perspective) and EUR 1,369 (societal perspective) per prevented DMFS.

In the NOCTP group, the largest investments in terms of health care costs were made in the first year of the trial (EUR 38 in the first year, EUR 30 in the second year and

DOI: 10.1159/000356859

EUR 23 in the third year). This is in line with the results found in an economic evaluation of an individually designed, patient-centred regimen for caries control performed in Finland [Hietasalo et al., 2009]. In both studies, the costs of the experimental group dropped below the costs of regular care in the third year. In Hietasalo et al.'s study [2009] the ICER was EUR 34 per prevented DMFS from a health care system perspective, which is comparable to our findings. A difference between both studies is that in the Finnish study, a major part of the protocol was conducted by dental hygienists. In the scenario analysis in the current study (where it was assumed that the programme was performed by dental hygienists), the NOCTP strategy was dominant when compared with regular care (i.e. resulted in lower costs and lower DMFS scores).

The NOCTP strategy indicated an increase in costs for the parents of EUR 14 over 3 years. In this study, the extra medical costs were covered by health insurance and therefore not directly paid for by the parent. Although the parental investment in terms of travel time, accompanying time and number of visits did not differ significantly in this study in the third year, there were notable differences in the first year. The fact that extra efforts of the parents are expected in the first year may hamper implementation of and adherence to the NOCTP regimen. A proportion of the parents indicated the burden of travelling/sacrificing spare time as a reason to quit participation. This emphasises this possible barrier in successfully implementing the NOCTP programme. Compliance may be increased if parents and children are informed of all benefits and disadvantages in advance. Therefore, if one wishes to implement the NOCTP strategy, it will be important to comprehensively introduce the protocol to parents and to emphasise that the increased demand on parents will, in most cases, be temporary.

Several limitations of our study need noticing. First, all calculations were based on the results of a relatively small research population (n = 230). Second, the follow-up time was relatively short to capture the effects of different caries prevention strategies. Third, the dropout rate of 22% can be considered as quite high. Although this percentage is comparable to those of other clinical trials in dentistry [Machiulskiene et al., 2002; Carvalho et al., 2010], the dropouts were not equally distributed among the treatment regimens. The reasons for withdrawal differed between the groups: in the NOCTP group, the main reason was the burden of travelling and insecurity on the validity of the programme, while in the IPFA group, the most reported reason was a perceived inconvenience for the child (e.g. tray with fluoride gel). In the control group, withdrawal was found to be lowest, probably because this was regular care which parents were used to. This may indicate that the IPFA and the NOCTP programme are (considered to be) more burdensome than regular care. Moreover, this raises the question of whether the subjects who remained in the study were a selective group; the most engaged parents may have been more likely to follow through with the regimen. Fourth, we replaced missing values (with multiple imputation) based on outcome measures of respondents of the same treatment group with similar characteristics. This may have resulted in bias in favour of the NOCTP and the IPFA group. A fifth limitation of our study is that our cost-effectiveness outcomes (as is commonly done in economic evaluations) are interpreted as if the marginal value of health benefits and the costs to gain them are constant. In other words, the societal value per prevented DMFS is held constant, regardless of how many DMFS would be prevented by implementing the NOCTP strategy. The same applies to the marginal costs of preventing one DMFS. In reality, both quantities may fluctuate between contexts and over time.

Our results indicate that in a 3-year time period, the NOCTP strategy is more expensive than regular care. However, the NOCTP strategy may turn out to be cost-saving when it is applied over a longer period of time. In theory, delaying or preventing the start of the restorative cycle could result in considerable savings in future expenses on caries treatment. The lifetime economic impact of dental fillings was assessed by Anderson [2001] at approximately USD 1,800 per decayed tooth (USD 1,800 in 1997 is converted to approximately EUR 2,425 in 2012). Whether such savings will also be achieved in practice is difficult to predict, as it depends on several factors, for instance on the market behaviour of dental professionals. When faced with reduced income levels due to less caries treatment, the use of other dental care may be promoted (or, if possible, prices increased), hence restoring income levels (and expenditures) [Chandra et al., 2012].

Whether the findings of this study, based on a 3-year time period, imply that the NOCTP strategy can be considered cost-effective compared to regular care crucially depends on how much society is willing to pay for one extra prevented DMFS. If this willingness to pay exceeds about EUR 100, the probability of NOCTP being expected to be cost-effective exceeds 51% seen from a societal perspective and 85%, from a health care system perspective (fig. 2). To date, knowledge regarding the relationship between willingness to pay for (preventive) dental care and oral health outcomes is limited. However, a recent study on willingness to invest among parents of 6-year-old chil-

dren in the Netherlands reported an average total willingness to pay of EUR 31 per month to keep their children's teeth healthy until the age of 18 [Vermaire et al., 2012]. Obviously, this does not straightforwardly translate into the value of one avoided DMFS. In fact, on an individual level it is not directly possible to 'buy' one prevented DMFS. It is merely possible to 'buy' a reduction of the probability of a DMFS occurring. Therefore, it would be interesting to find out how much parents (and society at large) are willing to pay for reducing children's chances of developing a DMFS. Parents' willingness to invest time should be considered as well.

Moreover, in general it is important to realize that decision-making (both on the individual and on the societal level) involves opportunity costs. Resources spent on this intervention cannot be spent on other goods or services within or outside the health care sector. In willingness to pay studies taking an individual perspective, these opportunity costs can be considered taken into account by the given budget constraints (e.g. personal income). In other words, when respondents state their willingness to pay, it may be assumed that they are aware of the fact that purchasing one good implicitly means sacrificing some other good. The same obviously holds for decisions made by other decision-making bodies (e.g. governments), although the opportunity costs in those cases may be more abstract and potentially more easily ignored.

In this study, dentists performed the intervention in the NOCTP group. However, it may also be possible to introduce this intervention executed by dental hygienists. Therefore we investigated the impact on cost-effectiveness in the hypothetical situation that all preventive visits were performed by a dental hygienist instead of the dentist. The results of the scenario analysis imply that from a cost perspective, it may be favourable to have all preventive visits performed by a dental hygienist. Note that in this scenario it was assumed that the effectiveness of the programme is identical, irrespective of whether a dentist or a dental hygienist performs the programme. With the prevention of dental diseases being their core business, dental hygienists potentially may accomplish even higher efficacy and effectiveness of their preventive efforts. Both positive and negative results on these outcomes have been reported [Berndsen et al., 1993; Ohrn et al., 1996; Petersson and Brathall, 2000; Ohrn et al., 2008].

To date, little scientific attention has been paid to the cost-effectiveness of dental care, and economic evaluations in preventive dentistry are scarce. We encourage further research in this area. It would be interesting to investigate the (cost-)effectiveness of NOCTP in other age groups as well as in other dental settings, e.g. to examine the effects when all preventive visits were to be performed by a dental hygienist. It is important to emphasise that although cost-effectiveness studies form an important source of information for decision-makers, other aspects besides value for money may be relevant as well. This may pertain for instance to equity considerations, i.e. the wish to have a fair distribution of health over the population. Decision-makers moreover have to deal with affordability of health care. The budget impact of implementing the NOCTP strategy is therefore relevant. Studying the budget impact of implementing NOCTP strategies as well as other dental care interventions therefore remains important, preferably also in relation to opportunity costs within the health care sector. Furthermore, more research on willingness to pay for dental care (outcomes) is needed to enhance interpretations of cost-effectiveness outcomes in dental care. Further health economic studies in dental care, including ones that can bridge the gap to more generic health outcome measures (for example further studying the difficulties of use of quality-adjusted life years in dental care), would increase the comparability of the cost-effectiveness of dental care with other types of health care. Even if the impact of having a carious tooth on the general quality of life is limited on an individual level, the total societal impact may still be considerable because of the very high prevalence.

Conclusion

The NOCTP regimen was more effective and more costly than regular dental care. Based on the limited available amount of evidence regarding the willingness to pay for dental care, the benefits seem to outweigh the additional costs, implying that this is a cost-effective strategy. Increasing the number of professional fluoride applications resulted in a slight reduction of caries increment, but at higher costs than the NOCTP strategy. The results of this study confirm the findings in previous research. Therefore, implementing NOCTP on a larger scale should be considered.

Acknowledgements

The authors would like to thank Lucas Goossens, PhD, and Martine Hoogendoorn, PhD, of the Institute for Medical Technology Assessment (iMTA) of the Erasmus University Rotterdam for their help in the multiple imputation and bootstrapping process.

References

Anderson MH: Current concepts of dental caries and its prevention. Oper Dent 2001;6(suppl): 11–18.

Bagramian RA, Garcia-Godoy F, Volpe AR: The global increase in dental caries. A pending public health crisis. Am J Dent 2009;22:3–8.

Berndsen M, Eijkman MAJ, Hoogstraten J: Compliance perceived by Dutch periodontists and hygienists. J Clin Periodontol 1993;20:668–672.

Bonneux L, Birnie E: The discount rate in the economic evaluation of prevention: a thought experiment. J Epidemiol Community Health 2001;55:123–125.

Brouwer WBF, Niessen LW, Postma MJ, Rutten FFH: Need for differential discounting of costs and health effects in cost effectiveness analyses. BMJ 2005;331:446–448.

Campbell MK, Torgerson DJ: Bootstrapping: estimating confidence intervals for cost-effectiveness ratios. Q J Med 1999;92:177–182.

Carvalho JC, Thylstrup A, Ekstrand KR: Results after 3 years of non-operative occlusal caries treatment of erupting permanent first molars. Community Dent Oral Epidemiol 1992;20:187–192.

Carvalho TS, Sampaio FC, Diniz A, Bönecker M, van Amerongen WE: Two years survival rate of Class II ART restorations in primary molars using two ways to avoid saliva contamination. Int J Paediatr Dent 2010;20:419–425.

Chandra A, Cutler D, Song Z: Handbook of Health Economics, vol 2, chap 6. North Holland, Elsevier, 2012.

Claxton K, Paulden M, Gravelle H, Brouwer WBF, Culyer AJ: Discounting and decision making in the economic evaluation of health care technologies. Health Econ 2011;20:2–15.

College voor Zorgverzekeringen: Guidelines for pharmacoeconomic research, updated version, 2006. http://www.ispor.org/peguidelines/source/HTAGuidelinesNLupdated2006.pdf (Dutch version: http://www.cvz.nl/binaries/content/documents/zinl-www/documenten/rubrieken/pakket/pakketbeheer/0604-richtlijnen-voor-farmaco-economisch-onderzoek/Richtlijnen+voor+farmaco-economisch+onderzoek.pdf) (last accessed July 7, 2013).

Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GJ: Methods for the evaluation of health care programmes, ed 3. Oxford, Oxford University Press, 2005.

Ekstrand KR, Christiansen MEC: Outcomes of a non-operative caries treatment programme for children and adolescents. Caries Res 2005;39: 455–467.

Ekstrand KR, Kuzmina IN, Kuzmina E, Christiansen MEC: Two and a half-year outcome of caries-preventive programs offered to groups of children in the Solntsevsky district of Moscow. Caries Res 2000;34:8–19.

Hakkaart-van Roijen L, Tan SS, Bouwmans CAM: Manual for cost analysis, methods and fixed costs for economical evaluations in healthcare (in Dutch). College voor Zorgverzekeringen, updated version 2010. Diemen, CVZ, 2011.

Hausen H, Seppä L, Poutanen R, Niinimaa A, Lahti S, Kärkkäinen S, Pietilä I: Noninvasive control of dental caries in children with active initial lesions. Caries Res 2007;41:384–391.

Hietasalo P, Seppä L, Lahti S, Niinimaa A, Kallio J, Aronen P, Sintonen H, Hausen H: Cost-effectiveness of an experimental caries-control regimen in a 3.4-yr randomized clinical trial among 11–12-yr-old Finnish schoolchildren. Eur J Oral Sci 2009;117:728–733.

Horrocks S, Anderson E, Salisbury C: Systematic review of whether nurse practitioners working in primary care can provide equivalent care to doctors. BMJ 2002;324:819–823.

Jerkovic K, van Offenbeek MA, Slot DE, van der Schans CP: Changes in the professional domain of Dutch dental hygienists. Int J Dent Hyg 2010; 8:301–307.

Kalf RRJ, Schepman SM, Batenburg RS: Actual data on dental employment capacity in the Netherlands (in Dutch). Utrecht, Nivel, 2010.

Machiulskiene V, Nyvad B, Baelum V: Determinants of dropout in a community intervention trial on the caries-preventive effect of chewing gums. J Public Health Dent 2002;62:21–27.

Marinho VCC, Higgins JPT, Logan S, Sheiham A: Fluoride gels for preventing dental caries in children and adolescents. Cochrane Database Syst Rev 2002;2:CD002280.

Nivel/Dutch Consumers Association: Wachten op de (tand)arts [waiting for the dentist]. Consumentengids, February 2002, p 55.

Ohrn K, Crossner CG, Börgesson I, Taube A: Accuracy of dental hygienists in diagnosing dental decay. Community Dent Oral Epidemiol 1996; 24:182–186.

Ohrn K, Hakeberg M, Abrahamsson KH: Dental beliefs, patients' specific attitudes towards dentists and dental hygienists: a comparative study. Int J Dent Hyg 2008;6:205–213.

Petersen PE: The World Oral Health Report 2003: continuous improvement of oral health in the 21st century – the approach of the WHO Global Oral Health Programme. Community Dent Oral Epidemiol 2003;31(suppl 1):3–23.

Petersson GH, Brathall D: Caries risk assessment: a comparison between the computer program 'Cariogram', dental hygienists and dentists. Swed Dent J 2000;24:129–137.

Poorterman JHG, Schuller AA: Tandheelkundige verzorging van jeugdige ziekenfondsverzekerden (TJZ) [Dental care among Dutch National Health Service insured children; final measurement 2005]. ACTA/TNO survey. Amsterdam, ACTA, 2006.

Poos MJJC, Smit JM, Groen J, Kommer GJ, Slobbe LCJ: Kosten van Ziekten [Costs of diseases in the Netherlands 2005]. Bilthoven, RIVM, 2008.

Schuller AA, van Kempen IPF, Poorterman JHG, Verrips GHW: Kies voor tanden [A survey on oral health and preventive behaviour of young people in the Netherlands]. Leiden, TNO, 2013.

Slobbe LCJ, Smit JM, Groen J, Poos MJJC, Kommer GJ: Costs of illness in the Netherlands 2007; trends in Dutch health expenditures 1999–2010 (in Dutch). Bilthoven, RIVM, 2011. http://www.kostenvanziekten.nl/systeem/service-menu-rechts/english/.

Tan SS, Bouwmans CA, Rutten FF, Hakkaart-van Roijen L: Update of the Dutch manual for costing in economic evaluations. Int J Technol Assess Health Care 2012;28:152–158.

Vermaire JH, van Exel NJ, van Loveren C, Brouwer WBF: Putting your money where your mouth is: parents' valuation of good oral health of their children. Soc Sci Med 2012;75:2200–2206.